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TECHNICAL REPORT

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PREDICTING TRANSIONOSPHERIC PROPAGATION CONDITIONS

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S U M M A R Y

A scheme is developed for predicting propagation conditions on transionospheric circuits. The scheme combines a realistic model of F-region irregularity behaviour with thin screen scintillation theory in order to simulate both the mean scintillation index and the probability of the signal falling below a nominated level. Consideration is given to the application of the prediction scheme to transionospheric circuits terminated by a synchronous satellite at 176.5°E (e.g. MARASAT II) and by points on the Earth's surface within an area bounded in latitude by 30°N and 65°S and in longitude by 75°E and 270° E. The duirnal and seasonal variations of the probability of disruption of such circuits is investigated under varying conditions of magnetic and sunspot activity. It is concluded that circuits, which terminate in a large and strategically important equatorial region and a small high latitude region, are likely to be disrupted at night. In the equatorial region the possibility of disruption is (a) highest during the equinoxes, (b) reduced by magnetic activity and (c) particularly severe during years of high sunspot activity. The bearing these factors have on the operational use of transionospheric circuits is briefly discussed.

Approved for Public Release

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1. INTRODUCTION

The most serious cause of disruption to space-Earth radio communications is of natural origin. It results from the phenomenon known as scintillation. In this phenomenon the steady signal at the receiver is replaced by one which is fluctuating in amplitude, phase and apparent direction of arrival. The phenomenon is not new. It was recognised in the early days of radio astronomy immediately after the Second World War. Indeed, the first extra-terrestrial radio sources or radio stars were recognised because they scintillated(ref.1). Subsequent investigation(ref.2) soon established that the signal fluctuations were introduced as the result of the passage of the radio wave through an irregular ionosphere. In particular, electron-density irregularities in the F-layer of the ionosphere are now known to be the prime cause of the fluctuations.

In the last two decades considerable effort has been expended in establishing the properties of the electron density irregularities in the F-layer(ref.3). Sufficient is now known so as to allow the behaviour of the irregularities to be modelled in an empirical way. The early models(ref.4,5) were based on a limited amount of scintillation data and neglected such important aspects as the dependence of the irregularity occurrence on magnetic activity and longitude. Recently, the ability to use spread-F data obtained from ionograms(ref.6) has added another dimension to the modelling process(ref.7,8) and more realistic models of the behaviour of the irregularities now exist(ref.8).

The next section outlines a model by means of which the nature and behaviour of the F-region irregularities can be simulated. It is shown that this model, coupled with the thin-screen theory of scintillation, leads to a means of predicting propagation conditions on transionospheric circuits. Section 3 then examines the application of the prediction scheme to circuits operating between a synchronous satellite at 176.5°E and the Earth's surface. Particular attention is paid to variations in latitude, longitude, day-of-year, time-of-day and the effects of changes in magnetic activity and sunspot number. The significence of these predictions is discussed in Section 4, while Section 5 concludes by summarizing the predictions and commenting on their operational significance.

2. THE MODEL

2.1 The propagation mechanism

If a plane radio wave is incident on a smooth horizontally stratified ionosphere it emerges as a plane wave. On the other hand, if there are irregularities of electron density embedded in the F layer, neighbouring parts of the wave traverse regions of different refractive index and the emerging wave front is distorted due to the correspondingly different phase propagation times. As the wave propagates away from the irregular layer, the phase distortions give rise to amplitude fluctuations(ref.9). That is, a diffraction pattern is developed. The depth of the amplitude fluctuations in this pattern increases with increasing distance from the irregular layer up to a limiting value, which persists as the wave travels on further. Passage of the irregularities overhead and/or movement of the source causes the diffraction pattern to move and hence a fluctuating signal is presented to a point receiver.

In order to quantify the fluctuations in the amplitude (R) of the scintillating signal, a quantity called the scintillation index (S) is defined as follows.

$$S = \left[\left\{ \overline{R^4} - (\overline{R^2})^2 \right\} / (\overline{R^2})^2 \right]^{\frac{1}{2}}$$

By considering first, the properities of the wavefront on emergence from the irregular region in terms of the properites of the ionization density irregularities and then dealing with the subsequent diffraction problem, it is possible to show(ref.9,10) that

$$S = f\left\{ \lambda, (\overline{\Delta N^2})^{\frac{1}{2}}, \Delta h, K_0, p, a, i, \psi, \theta, z_1, z_2 \right\} \qquad (1)$$

where λ = transmitting wavelength,

$(\overline{\Delta N^2})^{\frac{1}{2}}$ = the r.m.s. deviation of electron density in the irregularities.
Δh = thickness of the irregular layer,
K_0 = outer-scale wavenumber of the irregularity spectrum,
p = the spectral index of the irregularity spatial spectrum,
a = irregularity elongation factor along the Earth's magnetic field,
i = angle of incidence of the wave on the ionosphere,
ψ = angle between the direction of propagation and the Earth's magnetic field,
θ = angle between the direction of irregularity elongation normal to the Earth's magnetic field and the normal to the plane containing the direction of propagation and the magnetic field,
z_1 = the distance of the receiver from the irregularities and
z_2 = the distance of the transmitter from the irregularities.

This expression is valid if the deviations of phase across the emergent wavefront are less than one radian. For phase deviations greater than this, a strong scattering approximation must be used and values of S greater than one may be encountered. This condition is referred to as saturation(ref.11).

The variables λ, i, ψ, θ, z_1 and z_2 in the function f (equation (1)) are directly dependent on the transmitter, ionosphere and receiver configuration and can be easily determined in any particular case. On the other hand, the quantities $(\overline{\Delta N^2})^{\frac{1}{2}}$, $\Delta h, K_0, p, a$ describe the nature of the irregular region.

2.2 The nature of the irregularities

The gross features of the nature and behaviour of ionospheric irregularities have been determined by means of innumerable studies involving scintillations(ref.3), spread F(ref.12) and in-situ measurements(ref.13). Initially Fremouw and Bates(ref.4) and Fremouw and Rino(ref.5) summarized those properties of F-region irregularities, which can be determined by means of the scintillation phenomenon, in terms of a set of empirical equations. These expressed $(\overline{\Delta N^2})^{\frac{1}{2}}$ as a function of year, day-of-year, time-of-day, latitude, longitude and running average sunspot number (RASN). By employing spread-F data(ref.12), which is more plentiful than scintillation data, Singleton(ref.6,7) was able to further define the role of the sunspot cycle in these equations as well as include effects due to changing magnetic activity and longitude. Temporal variations of Δh and latitude variations of K_0 and a were also included in this model. The result(ref.8) is a set of empirical relations which give, in analytic form, a realistic expression of the nature of the irregularities responsible for scintillation on transionospheric circuits.

2.3 Predicting scintillation index

By combining the results of the scintillation theory (equation (1)) with the model of irregularity behaviour described in Section 2.2, it is possible to give analytic expression to the manner in which the scintillation index, observed on any transionospheric circuit, varies with such parameters as the positions of the terminals of the circuit, year, day-of-year, hour-of-day, magnetic activity, sunspot number and operating frequency. Computer programs have been written which embody this analytic formulation and which thereby allow the prediction of scintillation index for various transionospheric propagation circuits.

Figure 1 shows an output from one such program. Here a transmitting satellite at synchronous height over the equator at 176.5°E is considered. Contours of equal scintillation index are drawn for reception points on a map of the area between 30°N and 66°S geographic latitude and 75° to 270°E geographic longitude. Note the contours are limited necessarily to that part of the Earth's surface in view of the satellite (i.e. within the horizon curves on the figure). The area of prime interest to the Australian Navy (between the 90°E and 30°W meridians of longitude and between the 25°N and 60°S parallels of latitude) is also indicated on the figure. This particular diagram represents the predicted behaviour of all possible transionospheric circuits operating on day 80 of 1977 at 1200 hours UT. A frequency of 257 MHz, which correspondes to the down-link frequency of MARASAT II, was employed in the calculations. The expected running average sunspot number (RASN) at this time was 20 and the sum of the Kp figures for the day (SKp) was taken as 5. Local time is indicated across the top of the diagram.

Two regions of high scintillation activity are indicated in figure 1. One along the geomagnetic equator and a second at high latitudes. There is only slight activity in the middle latitudes. Note that at this time the scintillation index becomes saturated rather rapidly at the high geomagnetic latitudes, while saturation does not occur in the equatorial region. It should be recalled that the figure is a prediction of the mean scintillation index. No indication is given of the extent of the scatter individual observations of scintillation index at this time might have about the mean.

Equation (1) shows that the scintillation index depends on the distance of the receiver from the irregularities (z_1) and the distance of the transmitter from the irregularities (z_2). However, the nature of this dependence is such that, in any particular case, the interchange of z_1 and z_2 does not alter the value of S. Thus for a two way communication system, the scintillation index expected on the up link should be the same as that predicted for the down link.

2.4 Predicting disruption probability

Scintillation index proves to be a convenient measure of scintillation activity when the observation of scintillation is used as a technique for studying ionospheric irregularities. However, in the engineering of communication circuits employing transionospheric propagation, a more system oriented measure is needed, such as the probability of communication being lost due to scintillation effects. For most communication systems, the "outage" probability can be defined quantitatively as the probability of the signal level falling below some designated value. This threshold signal level is usually the noise level and, in this case, the maximum allowable fade margin is equal to the signal-to-noise ratio in dB. Hereafter, the probability of the signal falling below the fade margin will be called the disruption probability and its relationship to the scintillation index will now be examined.

Whitney et al(ref.14) demonstrated that the probability distribution of signal amplitude (R) for a scintillating signal is closely represented by

the Nakagami m distribution(ref.15). This is

$$P(R) = \frac{2m^m R^{2m-1}}{\Gamma(m)(\overline{R^2})^2} \exp(-mR^2/\overline{R^2})$$

where m can be shown to be $1/S^2$. Defining signal level χ as

$$\chi = 10 \log_{10} (R^2/\overline{R^2})$$

it follows from the Nakagami distribution that the probability of the signal level falling below some specified level χ_0 is

$$P(\chi_0) = \int_{-\infty}^{\chi_0} \frac{2m^m}{M\Gamma(m)} \exp\left[m\{ 2\chi/M - \exp(2\chi/M) \} \right] d\chi \qquad (2)$$

where $M = 20 \log_{10} e$. Thus, if χ_0 is the threshold of the fade margin, then $P(\chi_0)$ corresponds to the disruption probability.

The integral in equation (2) is readily evaluated and since $S = m^{-\frac{1}{2}}$, it allows predictions of mean scintillation index to be converted to predictions of disruption probability. Figure 2 is the disruption-probability prediction corresponding to the scintillation-index prediction of figure 1. Here disruption probability (expressed as a percentage) for a fade margin of -6 dB is plotted as a series of contours on the same map as that used for figure 1.

As expected, figure 2 has similar characteristics to figure 1. The areas affected by scintillation appear to be slightly reduced in terms of signal level probability as compared with the scintillation index indication. This merely reflects the fact that, under weak scintillation conditions, the probability of 6 dB fades is low. Note also that the scintillation index to disruption probability conversion is only possible where the scintillation index $\leqslant 1$. The model is unable to comment on disruption probability where the scintillation index is saturated, except to say that the disruption probability in the saturated region will be higher than the disruption probability just outside this region. Thus at high latitudes immediately south of Australia, the disruption probability rapidly increases to values in excess of the saturation value which is itself in excess of 15%.

From the above it will be seen that equation (2), coupled with equation (1) and the model of ionospheric irregularities discussed in Section 2.2, provides the engineer designing a transionospheric propagation circuit with a means of determining the fading margins necessary to overcome scintillation effects under various conditions. In order to evaluate the performance of a proposed system, disruption probabilities for various critical signal levels are usually needed as a function of latitude, longitude, time-of-day, season, level of magnetic activity and phase of the sunspot cycle. The next section illustrates such a performance evaluation for MARASAT II as it likely to be used by the Australian Navy.

3. THE MODEL'S PREDICTIONS

3.1 Variations with latitude and longitude

Consider the case of a communications satellite at synchronous height over the equator at 176.5°E with up-link and down-link frequencies near 257 MHz. If the fade margin allowed is 6 dB, then the instantaneous picture at 1600 hours UT of the likelihood of disruption to both the down- and up-link transmissions over a wide geographical area is as shown in figure 2. As indicated earlier, the likelihood of disruption to these circuits is limited to those terminating in the equatorial and high latitude regions. This style of presentation will be used in the following sections to examine how the geographic distribution of circuit performance varies with time-of-day, season, magnetic activity, sunspot cycle and critical level.

3.2 Diurnal variations

The diurnal development of the equatorial and high latitude areas of scintillation activity is illustrated in figure 3. In figure 3(a) the western half of the diagram is experiencing late morning, noon and afternoon conditions for which there is little scintillation activity in either the equatorial or high latitude regions. Activity in the equatorial region rapidly builds up on the satellites eastern horizon however, where late evening conditions prevail.

The instantaneous picture six hours later at 1000 hours UT (figure 3(b)) shows that the equatorial region of high activity has moved out over the mid-Pacific Ocean and the probability of circuit disruption at the 6 dB level increases from a maximum of 8% to one of 10%. At the high latitudes during the 6 hours between the instantaneous pictures of figures 3(a) and (b), the affected region moves equatorwards and the maximum disruption probability increases from 6% to something in excess of 15%. During the next four hours to 1400 hours UT (figure 3(c)), the equatorial activity moves to the north of Australia and weakens somewhat (except right on the horizon), while the high latitude activity continues its movement towards the equator. By 1800 hours UT (figure 3(d)), the equatorial activity has retreated into the western horizon of the satellites field of view and the high latitude activity has started to fall back towards the South Pole. Thus the high activity in the equatorial region moves along the geomagnetic equator being roughly centred on a time during the hour before local midnight. Note that the likelihood of disturbance to a transionospheric curcuit is greater when the irregular ionosphere intersects radiation directed towards the satellite's horizon, than when it is more nearly under the satellite. This is a result of the well known zenith angle effect on scintillation namely, the scintillation effect produced by a given irregularity configuration increases as the zenith angle of the transmitter increases.

In the distrubed high latitude region, the disruption probability also maximizes and is closest to the equator during the hour before local midnight.

3.3 Seasonal variations

Figure 4 illustrates the main features of the seasonal variation of disruption probability. In the equatorial region of high scintillation activity, the likelihood of disturbance to a transionospheric circuit is greatest in the equinoxes (figures 4(b) and (d)) where it can reach 10% at 1200 hours UT. In the solstice periods (figures 4(a) and (c)) and under the other conditions prevailing, there is little likelihood of circuit disruption.

In the high latitude region of high scintillation activity there is

little seasonal effect.

3.4 Magnetic activity variations

Magnetic activity affects the low and high latitude regions of high activity differently. This is shown in figure 5. The measure of the degree of magnetic activity used here is the sum (SKp) of the eight three-hourly planetary K figures for a day. In figure 5(a) SKp is 5. This is increased to 20, 30 and 40 in figures 5(b),(c) and (d) respectively.

The increase of SKp from 5 to 20 (figures 5(a) and (b)) affects the equatorial activity little. However, at the high latitudes, this SKp increase causes the active region to move some 3° towards the equator. Increasing SKp from 20 to 30 (figures 5(b) and (c)) takes the high latitude region only about 1° nearer the equator but causes a marked decrease in equatorial activity. The maximum equatorial disruption probability falls from 10% to 4%. A further increase of SKp by 10 (figures 5(c) and (d)) sees the equatorial activity disappear altogether, while there is a further slight movement of the high latitude active region towards the equator.

It is clear that magnetic activity ranks with geographic position, time-of-day and season as a factor which needs to be taken into account in determining the usefulness of a transionospheric circuit.

3.5 Sunspot cycle variation

Figure 6 illustrates the effect of the changing sunspot cycle on the disruption probability under equinoxial conditions. The disturbed equatorial region not only expands in size with increasing sunspot number but also increases in intensity. Increasing the sunspot number (RASN) from 10 through 20 to 30 (figures 6(a),(b) and (c)) causes the peak disruption probability to increase from 4% to 10% and on to 15%.

In the present sunspot cycle these values of RASN will be exceeded by mid 1978 and values well in excess of 100 will be encountered by 1980. Figure 6(d) gives an indication of the severe conditions which can be expected at that time. The whole equatorial (magnetic) region of the area of interest will be subject to circuit dislocations for much more than 15% of the time.

A further indication of the importance of the sunspot cycle effect in the equatorial region is given by figure 7. This depicts solstice conditions for which there is very little equatorial activity at sunspot minimum (figures 7(a), (b) and (c)) but which acquires considerable equatorial activity (disruption probability up to 15%) at sunspot maximum (figure 7(d)).

A factor which must be kept in mind when considering the sunspot maximum situation is that, at this part of the sunspot cycle, magnetic activity is both more common and more severe than at sunspot minimum. So that at the equator the magnetic inhibition effects described in Section 3.4 oppose the sunspot cycle increase in activity. As these two opposing effects have quite different time scales, they combine in practice to produce a very variable situation. This will range from relatively undisturbed transionospheric propagation conditions during severe magnetic storms to badly disturbed propagation when the magnetic conditions are quiet.

At the high latitudes the disturbed region appears to be altered little by increasing values of sunspot number when these are moderate values (figures 6(a), (b) and (c) and figures 7(a), (b) and (c)). At the higher sunspot numbers (figures 6(d) and 7(d)) there appears to be a slight contraction of the disturbed region towards the South Pole. This sunspot maximum picture is also modified by the opposing effect of magnetic activity at these latitudes (Section 3.4). Again considerable variability can be expected at sunspot maximum.

3.6 Changes in the critical level

Figure 8 illustrates the effect of changing the critical level or fade margin (χ_0) in the disruption probability calculations (equation (2)). Figures 8(a) to (d) inclusive, represent the same situation except the critical level is changed in 2 dB steps from -4 dB in figure 8(a) to -10 dB in figure 8(d). As expected, increasing the critical level or fade margin decreases both the area in which transionospheric propagation is likely to be disturbed by scintillation effects and the probability of such disturbance. This is true for both the equatorial and high latitude regions of high scintillation activity.

3.7 Single point diurnal and seasonal variations

Besides obtaining instataneous pictures of disruption probability over a large geographic area at various times of day, season, etc., it is also possible to employ the prediction scheme outlined in Section 2 to examine a particular circuit in detail. Here the two terminals of the transionospheric curcuit are fixed at known positions and the disruption probability is examined as a function of time-of-day and day-of-year for various operating frequencies, critical signal levels, SKp values and sunspot numbers.

Figures 9 and 10 show results obtained in this way for two circuits each originating at a satellite at synchronous height over the equator at 176.5°E (e.g. MARASAT II) and terminating at Manus Island (figure 9) and Guam (figure 10). The contours on these local time versus day-of-year diagrams respresent steps of equal disruption probability for a critical level of -6 dB and typical sunspot minimum conditions. It is immediately obvious that under these conditions these circuits are unlikely to be greatly disturbed. Any disturbences which do occur will be at night and this likelihood will be higher in the equinoxes than in either of the solstices. Note also that in each case, increasing SKp from 5 to 20 alters the situation little. However, if SKp is further increased to 30 or more, the disruption probability for both circuits is zero regardless of time of day (not shown in figures 9 and 10).

The sunspot cycle effect is quite marked on these two circuits. This effect is illustrated in figure 11 for Manus Island, which is at a geomagnetic latitude of 11° S and hence is towards the edge of the equatorial region of high scintillation activity. As already indicated, the possibility of disruption of the circuit is small under sunspot minimum conditions (figures 11(a),(b) and (c)). However, at sunspot maximum (figure 11(d)), the circuit is likely to be disturbed at night during all seasons, except the southern solstice, the probability being in excess of 15% during the equinoxes. Figure 12 shows that at Guam which, at about 4°N geomagnetic latitude, is deeper into the equatorial belt of high activity, there is an even bigger contrast between sunspot minimum behaviour and sunspot maximum behaviour. Here in each of the equinoxes at sunspot maximum, the disruption probability can be well in excess of 15% for seven hours each night for nearly 3 months. Again it should be remembered that because of the opposing effect of magnetic activity, the sunspot maximum behaviour on each of these circuits will be highly variable, fluctuating between the situation just described and considerably quieter conditions.

4. DISCUSSION

The prediction scheme used in the circuit performance evaluations described above finds a mean scintillation index which is then converted to a disruption probability (Section 2). No attempt is made to account for the scatter individual scintillation index observations will have about the predicted

value. The whole process of irregularity and propagation simulation is aimed at reducing this scatter. For instance, the present scheme is a vast improvement, in this respect, over using a simple estimate of mean index involving only a latitude variation. Obviously this scatter will be reduced further and the prediction scheme correspondingly improved as more variables are taken into account in the irregularity model.

The examples of the use of the prediction scheme employed to illustrate the discussion in the previous Sections have all been based on a satellite at synchronous height. It should be noted that the prediction scheme and indeed the current computer programs embodying this scheme, are equally applicable to orbiting satellites at any height.

5. CONCLUSIONS

It has been demonstrated that by combining scintillation theory with an empirical model of the behaviour of ionospheric irregularities, it is possible to produce a viable scheme for the prediction of scintillation index and the probability of the level of a scintillating signal falling below some particular level or fade margin. Of course the prediction scheme is only as good as the irregularity model used. However, as the result of improvements which have recently been made, the model is now quite realistic and allows meaningful simulations of transionospheric propagation circuits to be made.

The propagation circuit simulation technique has been illustrated here in terms of circuits involving MARASAT II as they are likely to be worked by the Australian Navy. The following properties of such circuits have been noted:

(a) While at 257 MHz scintillation occurs everywhere at some time, it is only sufficiently intense in two geographical areas so as to necessitate the specification of fading margins well in excess of 6 dB in order to avoid significant outages. The first of these areas is the equatorial zone which stetches in a 25° wide swath across the Pacific Ocean approximately centred on the geomagnetic equator. That is, it extends from the Peruvian coast across the Pacific Ocean between Samoa and the Hawaiian Islands, passes to the north of New Guinea, over the Philippines and northern Borneo and on to Vietnam, Tailand and southern India. A second zone of high activity exists at latitudes in excess of 50° S immediately to the south of Australia and New Zealand.

(b) The possibility of circuit disruption exists only at night in the equatorial region. In the high latitude region disruption is possible during the day as well as at night but the likelihood of daytime disturbances is considerably less.

(c) At the high latitudes of interest there is little change in the likelihood of circuit disruption with season. However, in the equatorial region, the likelihood of circuit disurption is greatest in the equinoxes.

(d) During the maximum of the sunspot cycle, the likelihood of circuit disruption in the equatorial region is much higher than at other parts of the cycle. Even during the solstices, disruption will occur up to 15% of the time with a fading margin of 6 dB in sunspot maximum, though no disruption occurs during these seasons in years of low sunspot number. In the equinoxes circuit disruptions will occur for more than 15% of the time over a wide area. At the high latitudes variations of sunspot number alter the situation little.

(e) Increased magnetic activity tends to decrease the likelihood of circuit disruption in the equatorial zone. During years of high

sunspot number this is likely to lead to an extremely variable situation. At the high latitudes, increased magnetic activity causes the region in which circuit disruption is likely to occur to move closer to the equator.

It is apparent from the above that transionospheric circuits with terminals in the equatorial region are likely to be disrupted at night due to scintillation. This will be true especially in years of high sunspot activity (e.g. 1979-1982). This may have a bearing on the operational use of such circuits in the equatorial area which is of some strategic importance. Prediction of quiet periods would be possible using the framework outlined above coupled with the predictions of magnetic activity issued by communications warning agencies such as the Ionospheric Prediction Service of the Department of Science. It is worth noting that, while periods of high magnetic activity bring quiet transionospheric propagation conditions to the equatorial ionosphere, conventional propagation via ionospheric reflection is often disturbed during periods of such activity.

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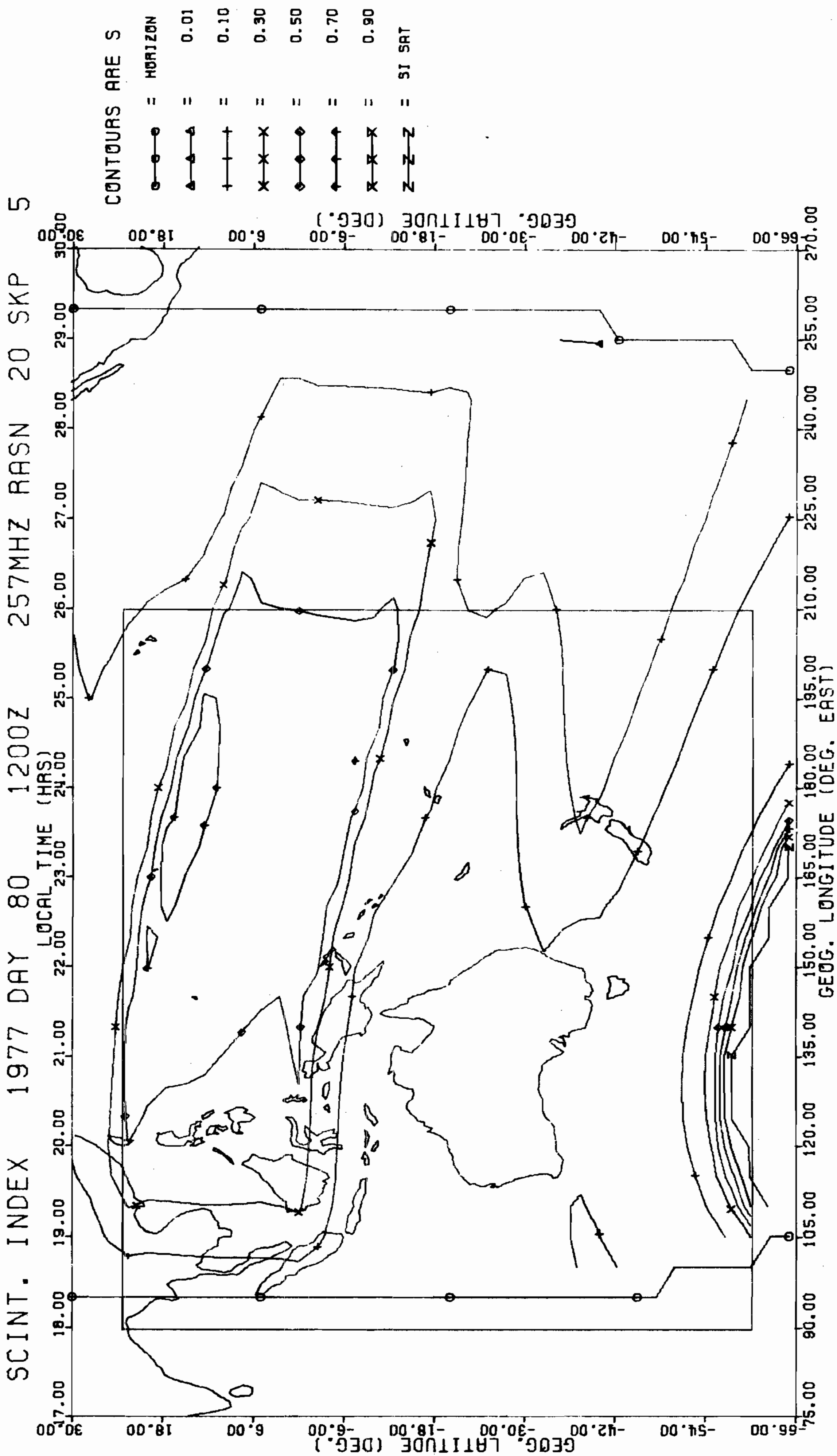


Figure 1. Contours of scintillation index (S) on a geographic latitude versus longitude map

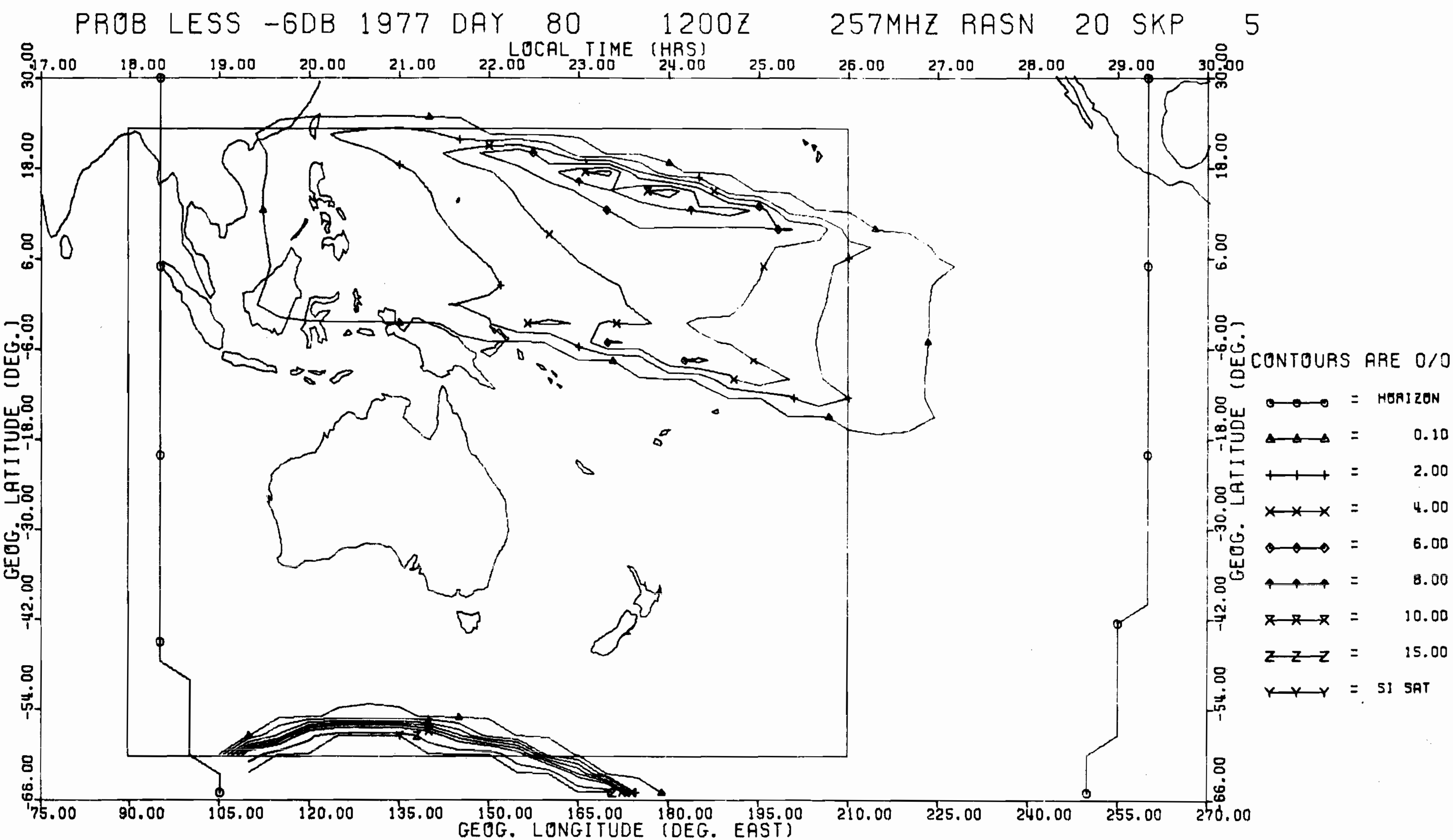


Figure 2. Contours of disruption probability (expressed as a percentage) for a fade margin of -6 dB on a geographic latitude versus longitude map

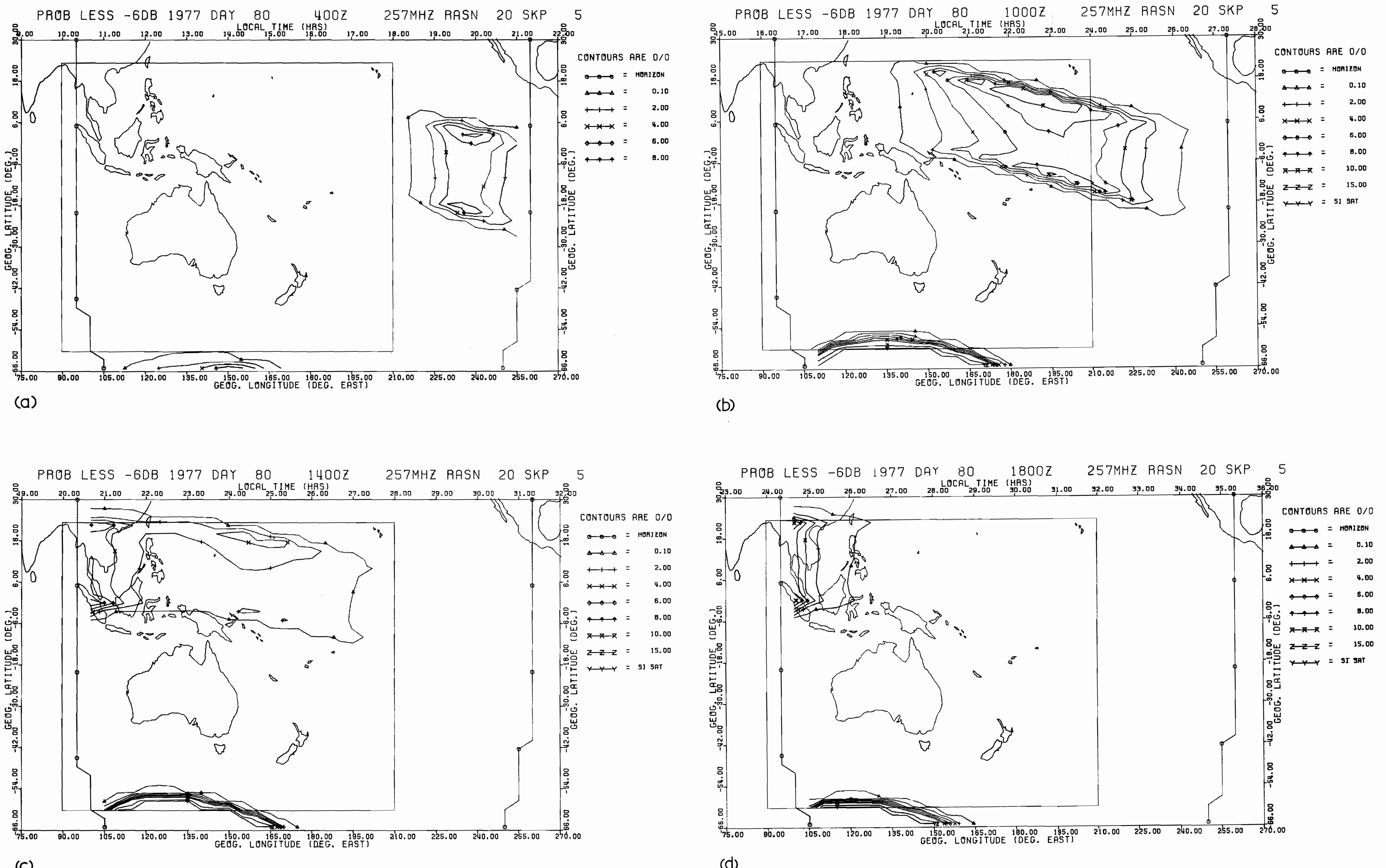


Figure 3. An illustration of the diurnal development of the equatorial and high latitude disturbed regions

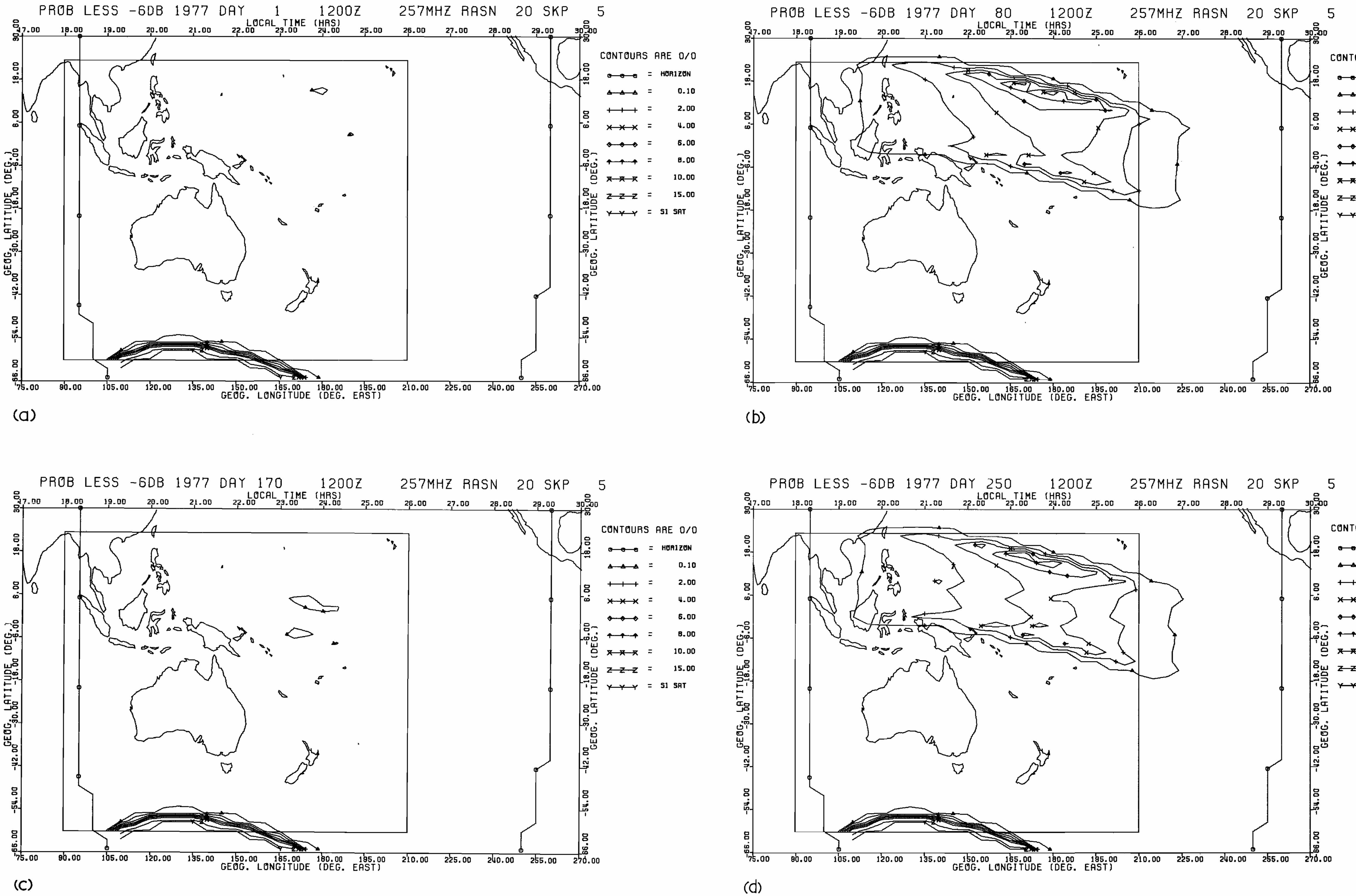
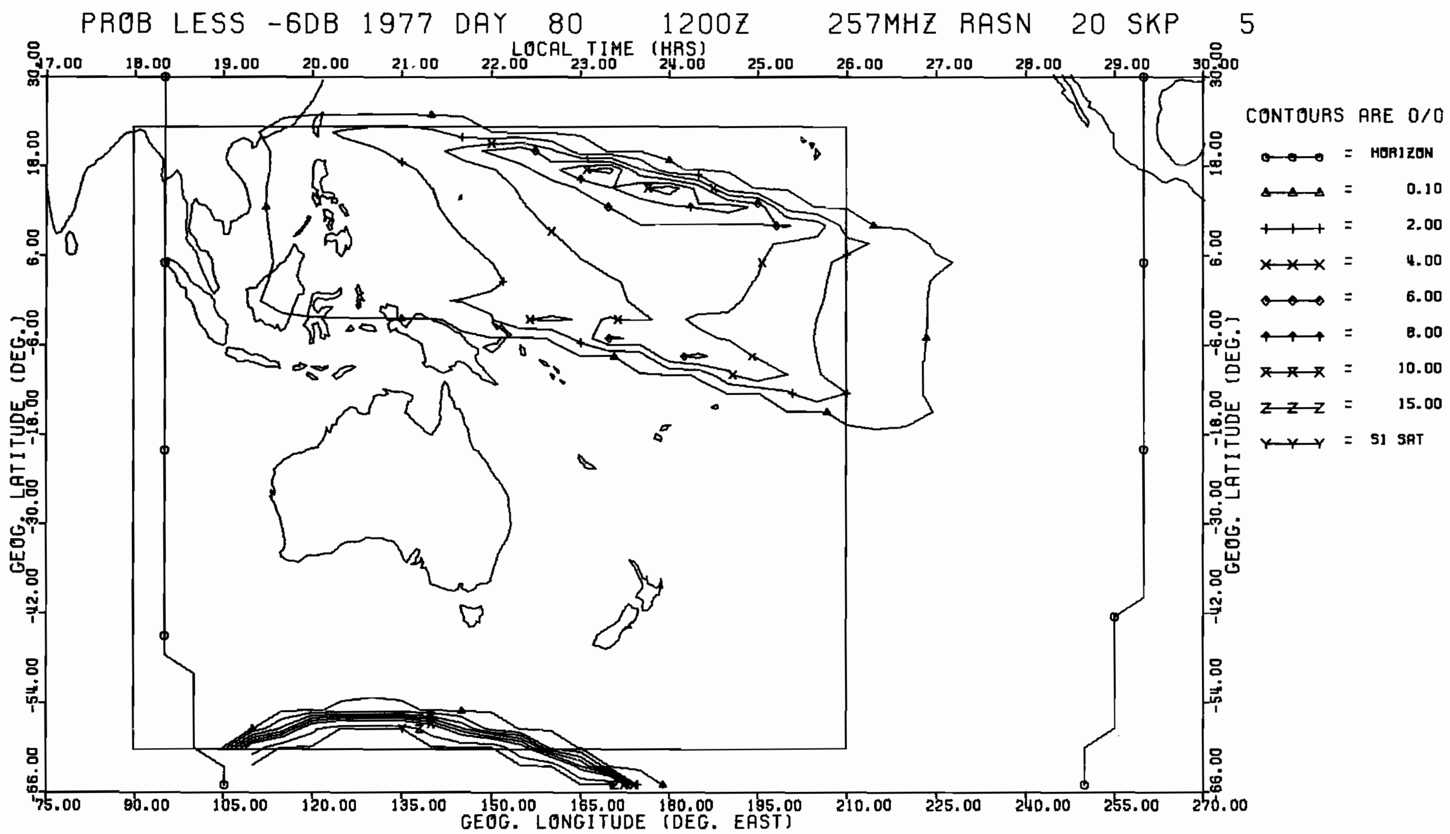
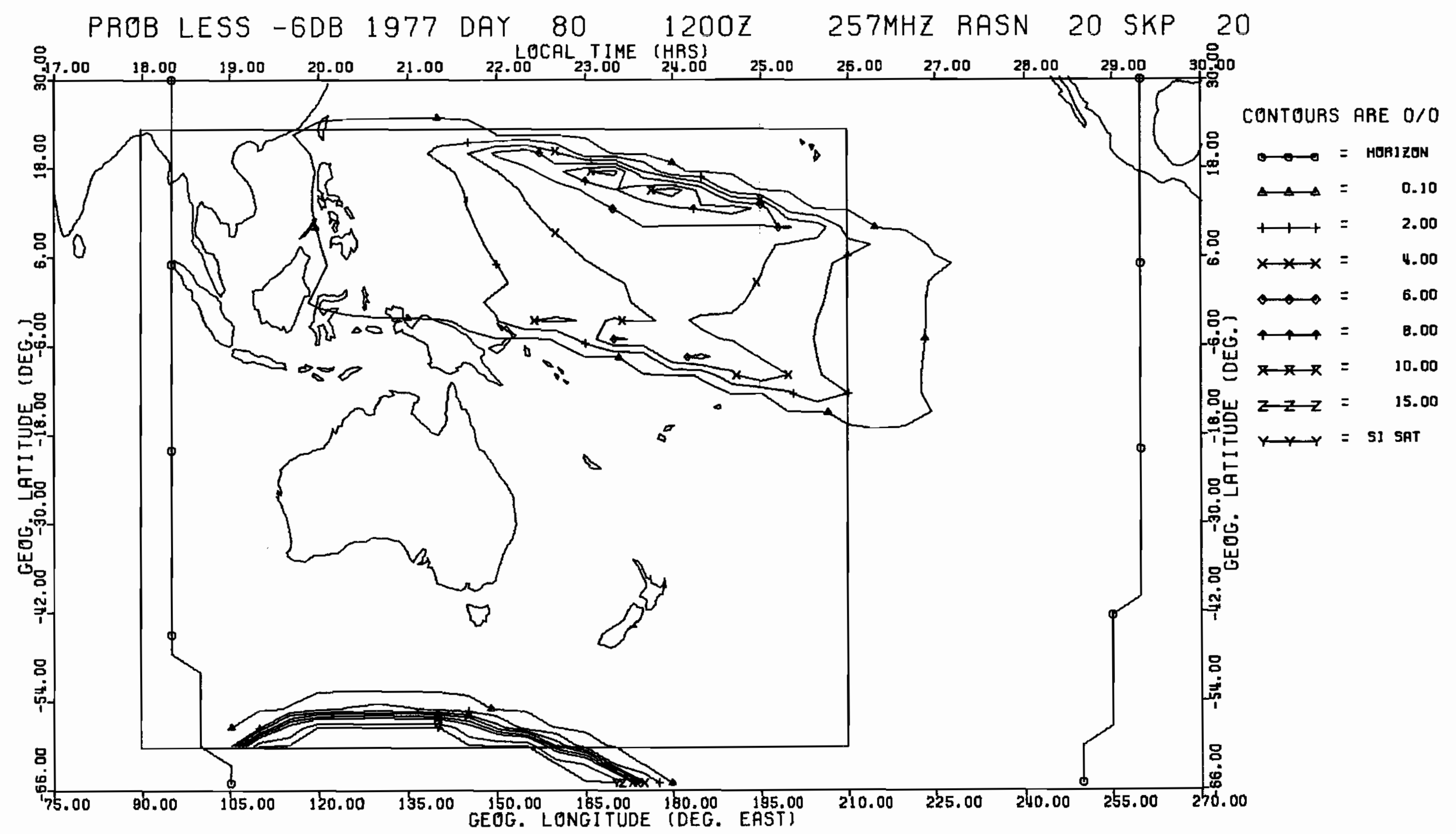


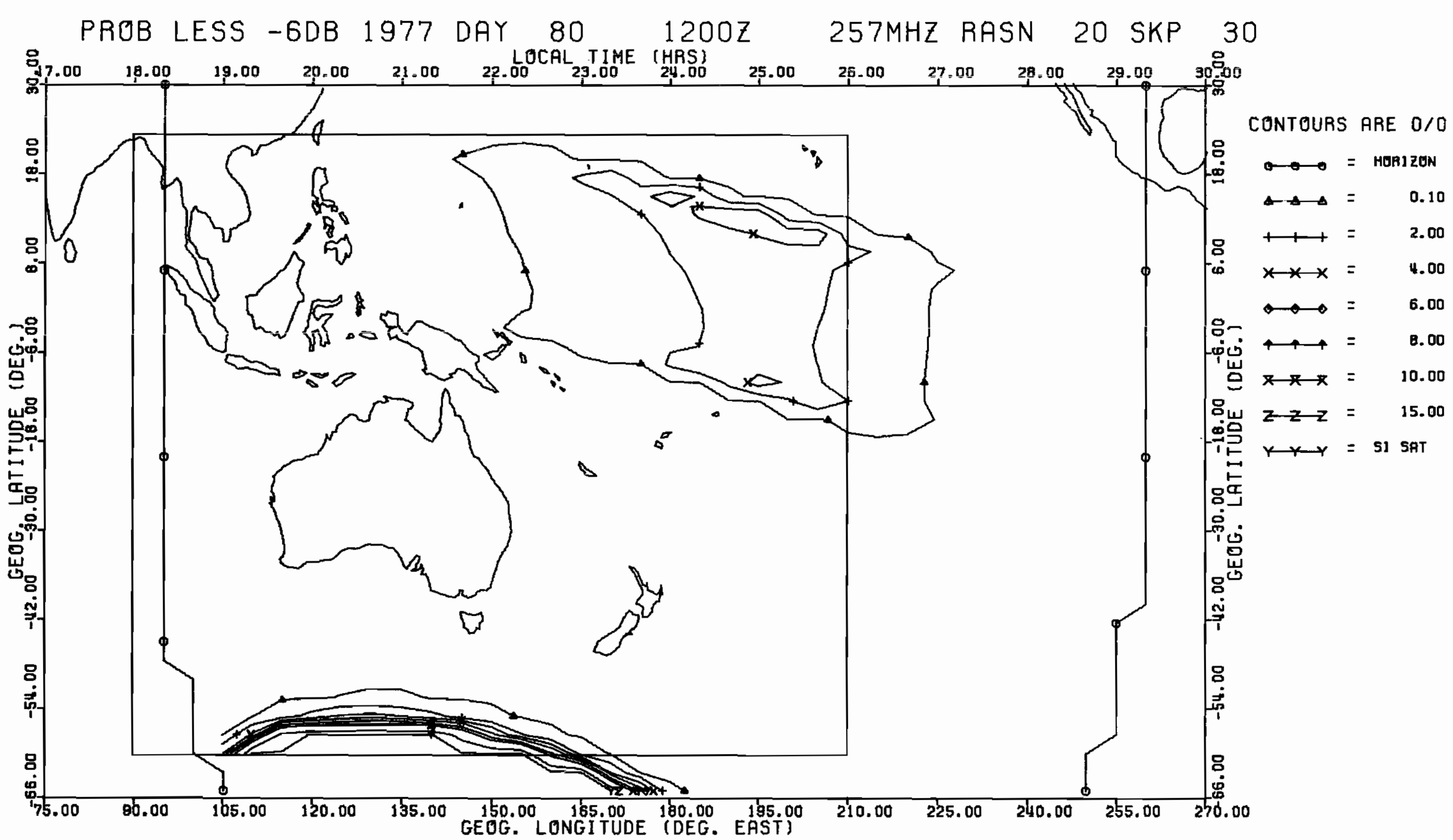
Figure 4. An illustration of the seasonal variation of the equatorial and high latitude disturbed regions



(a)



(b)



(c)

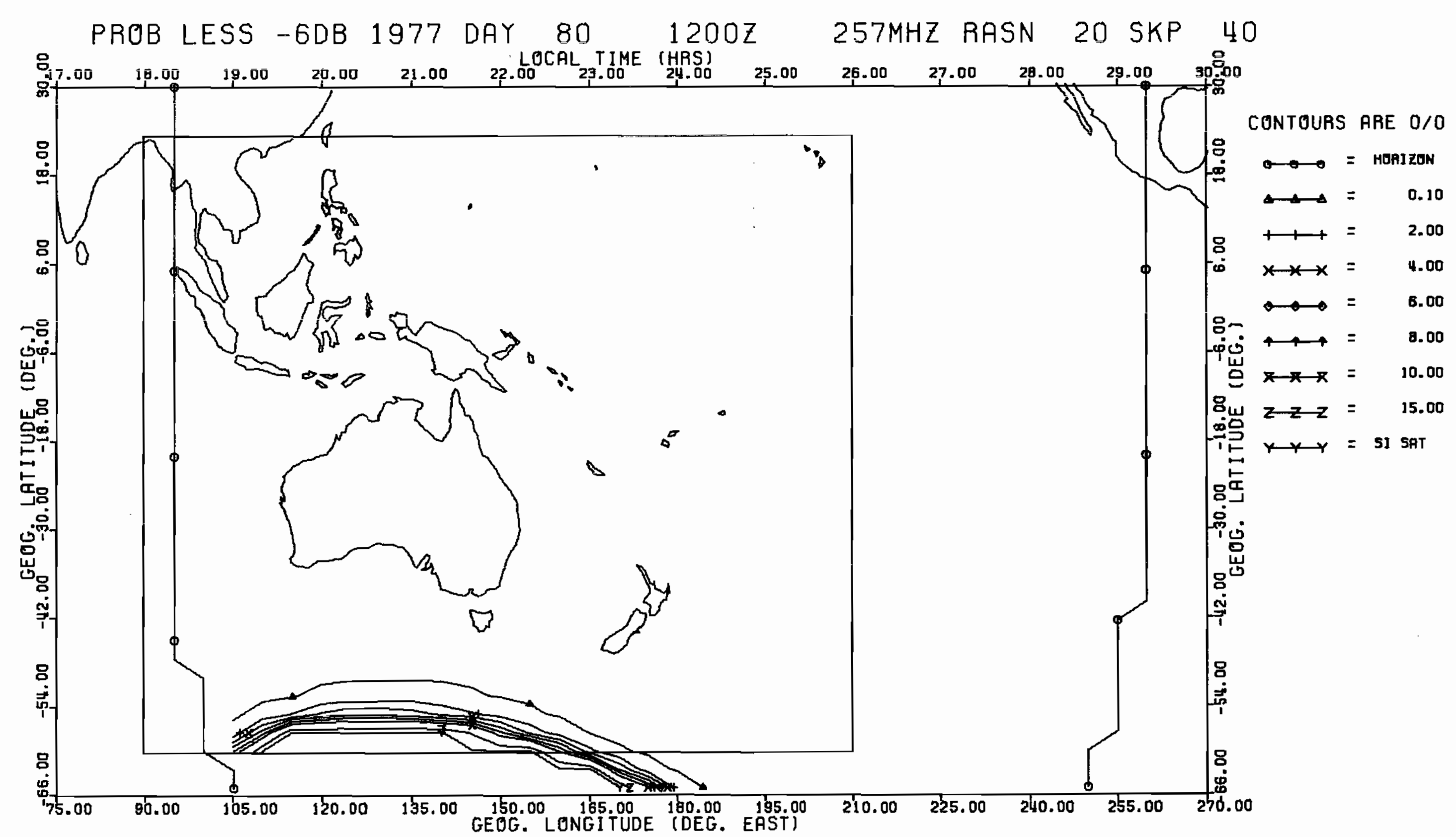


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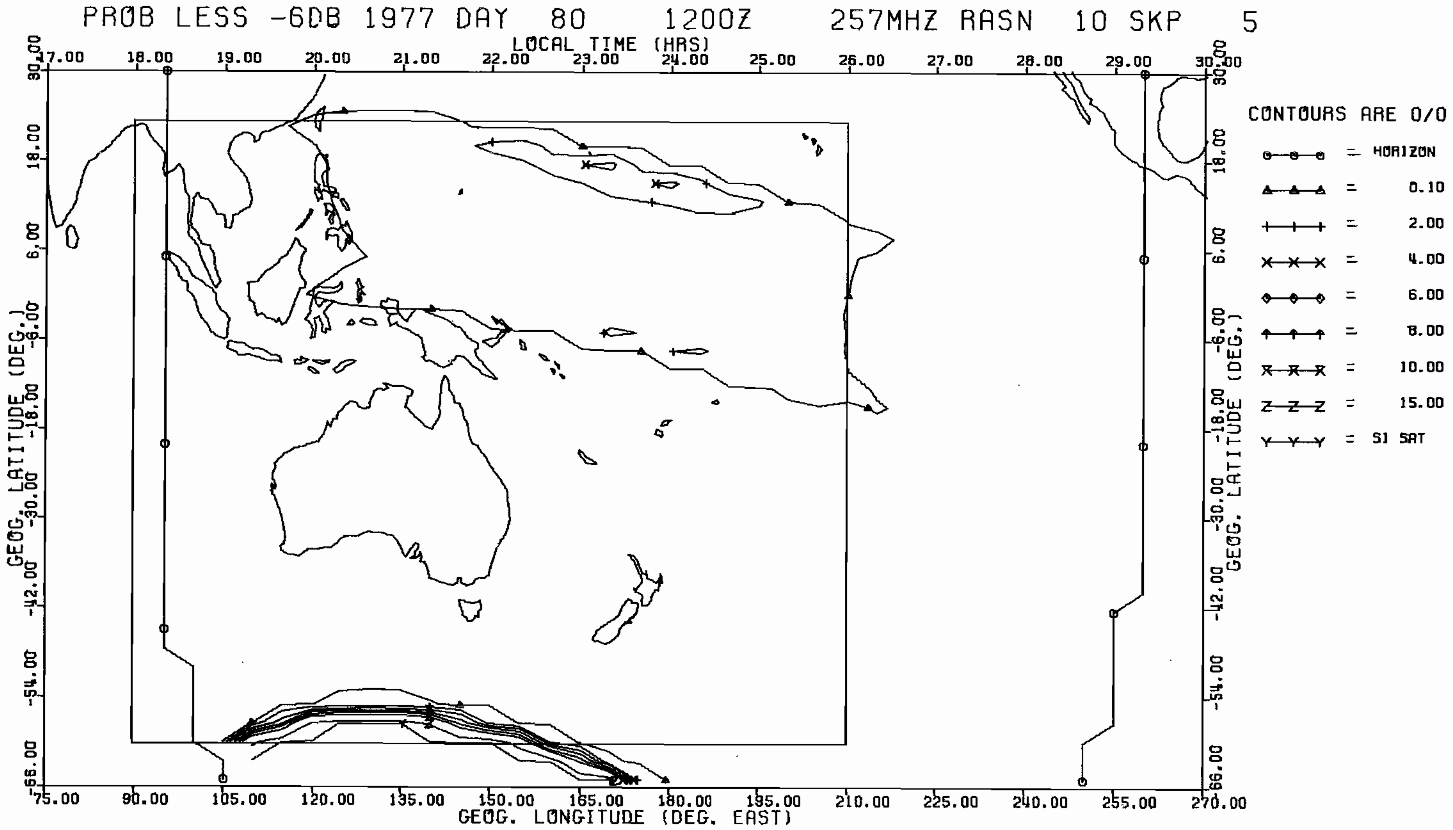
Figure 5. The effect of magnetic activity on the disruption probability in the disturbed regions



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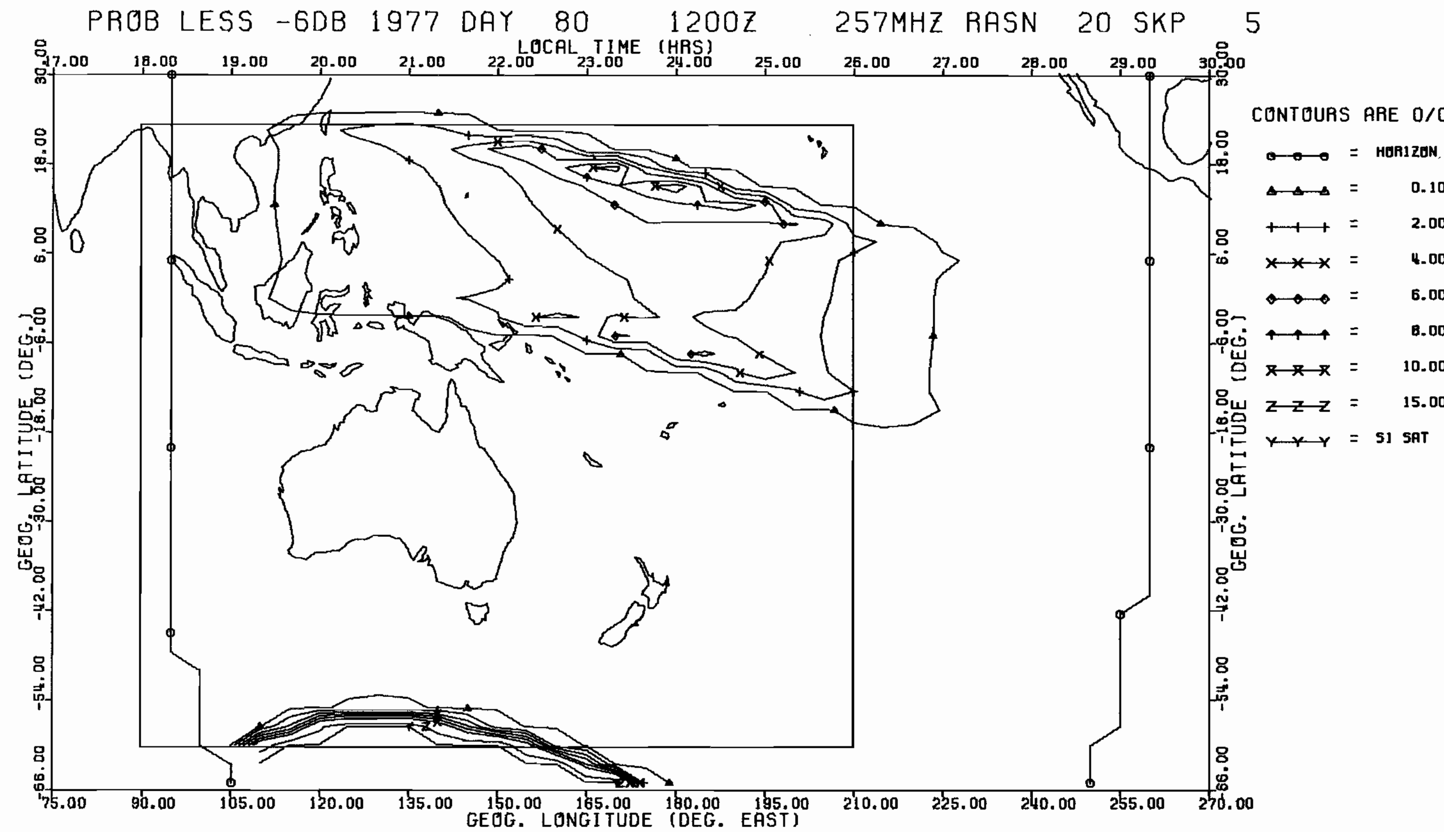

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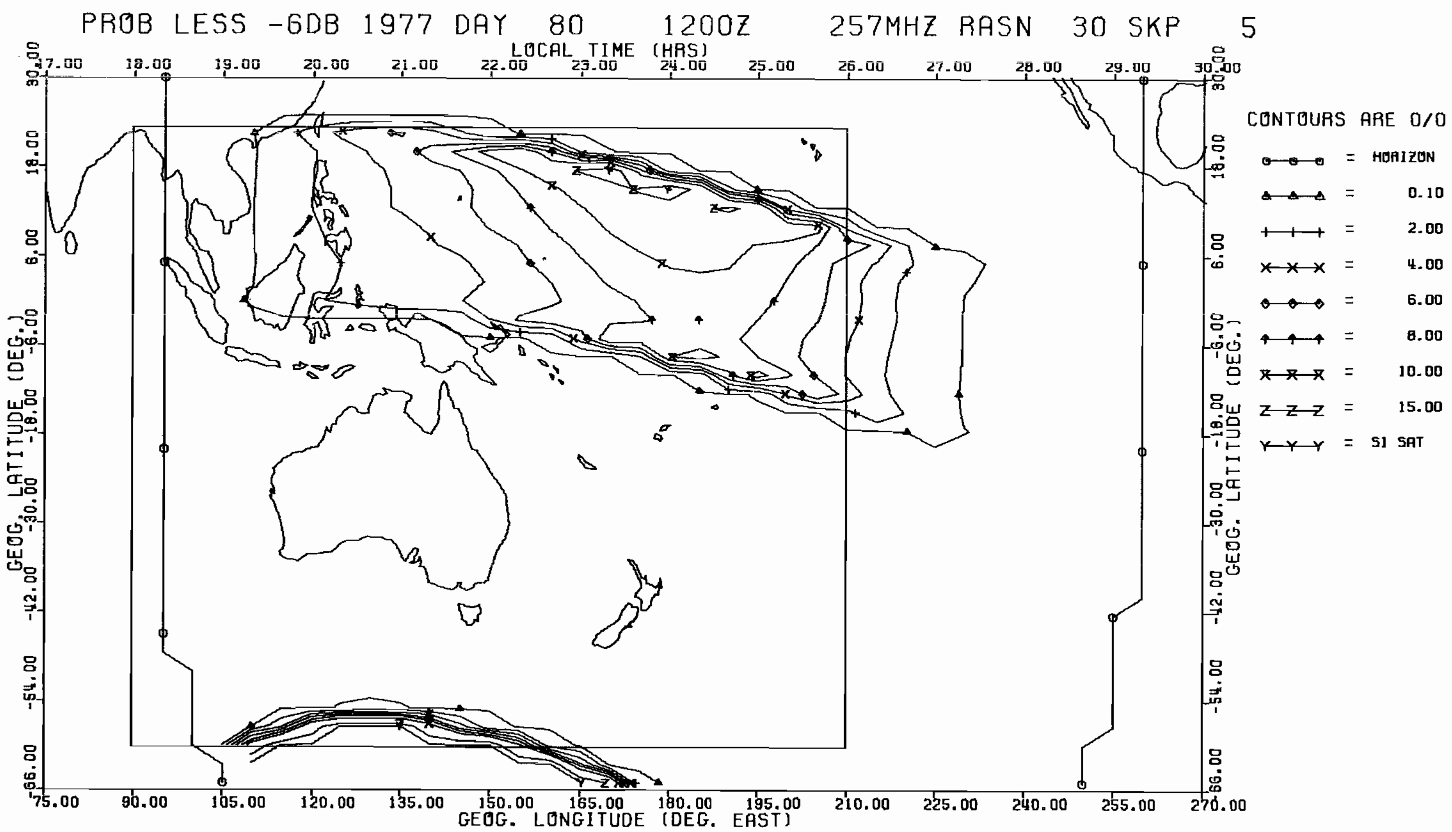

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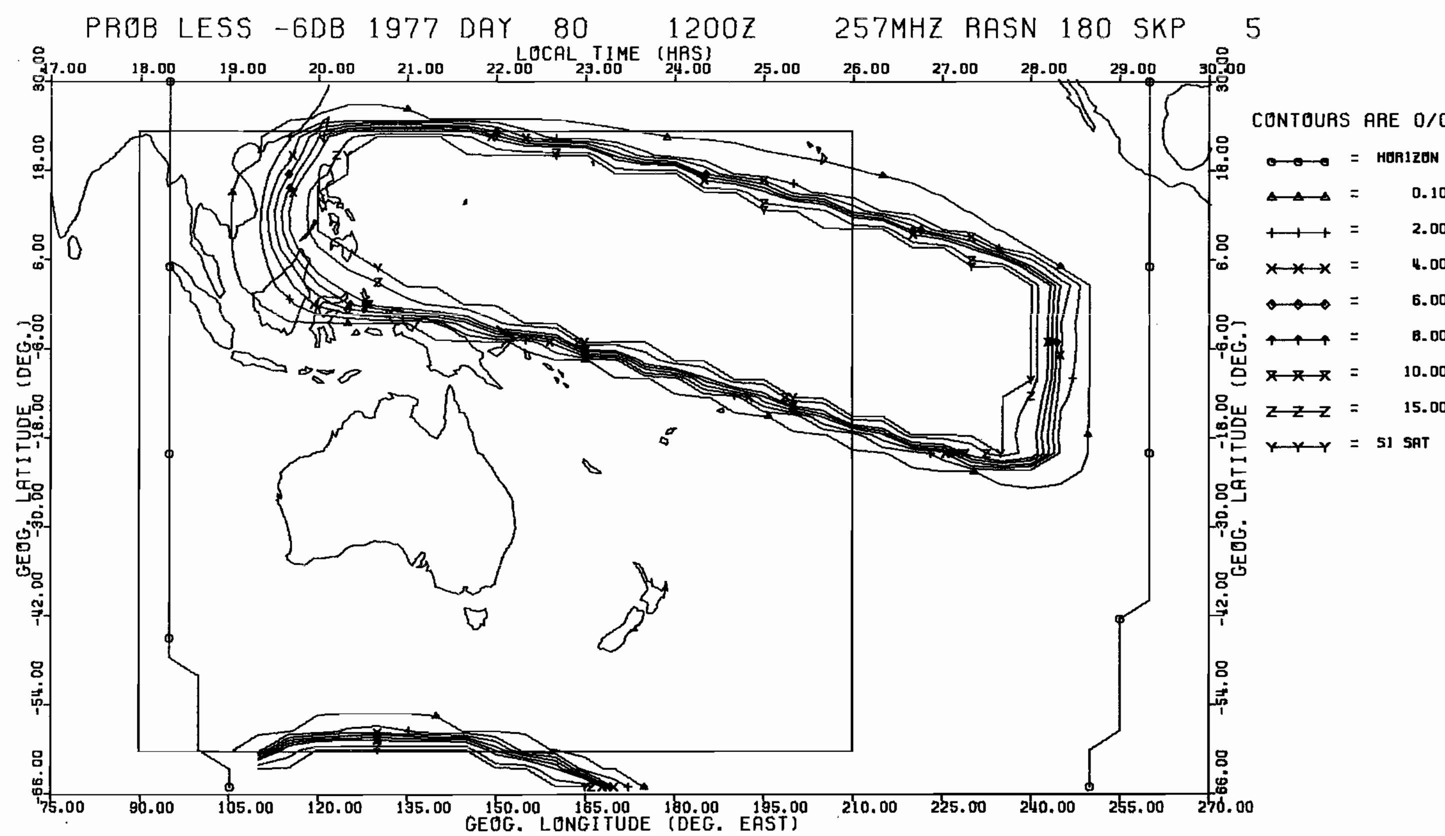

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Figure 6. The effect of sunspot activity on the disruption probability in the disturbed regions during the equinoxes

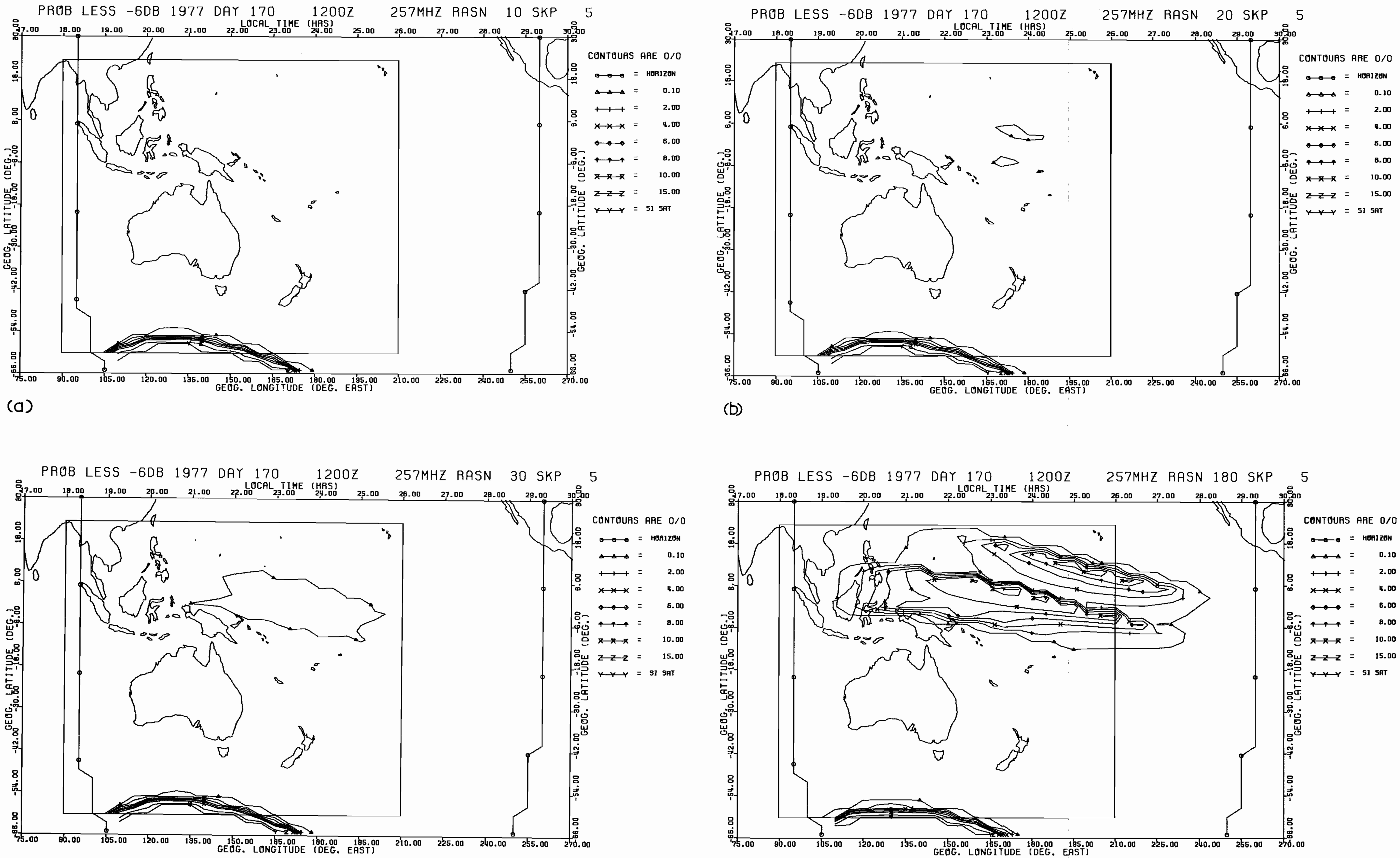


Figure 7. The effect of sunspot activity on the disruption probability in the disturbed regions during the solstices

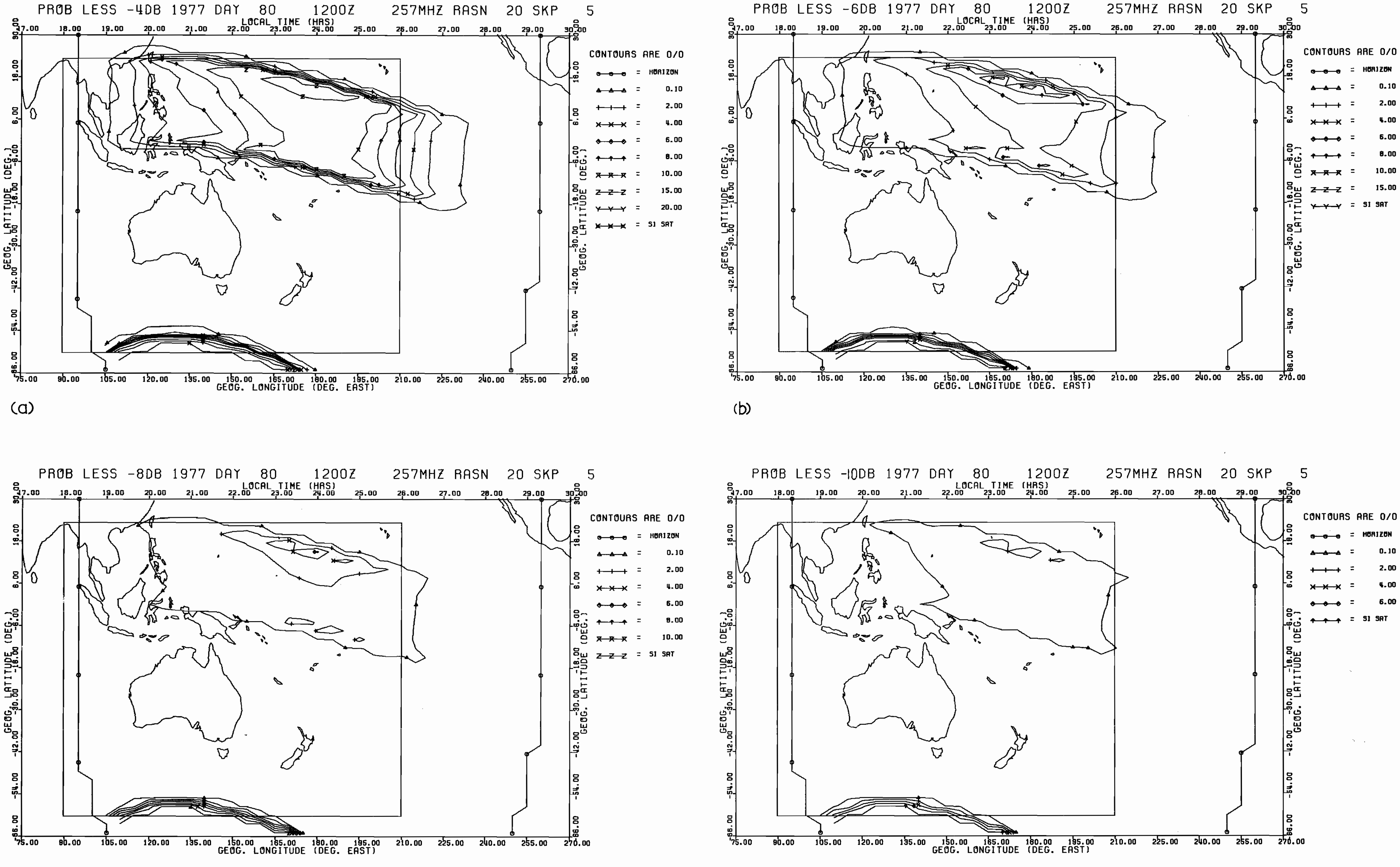
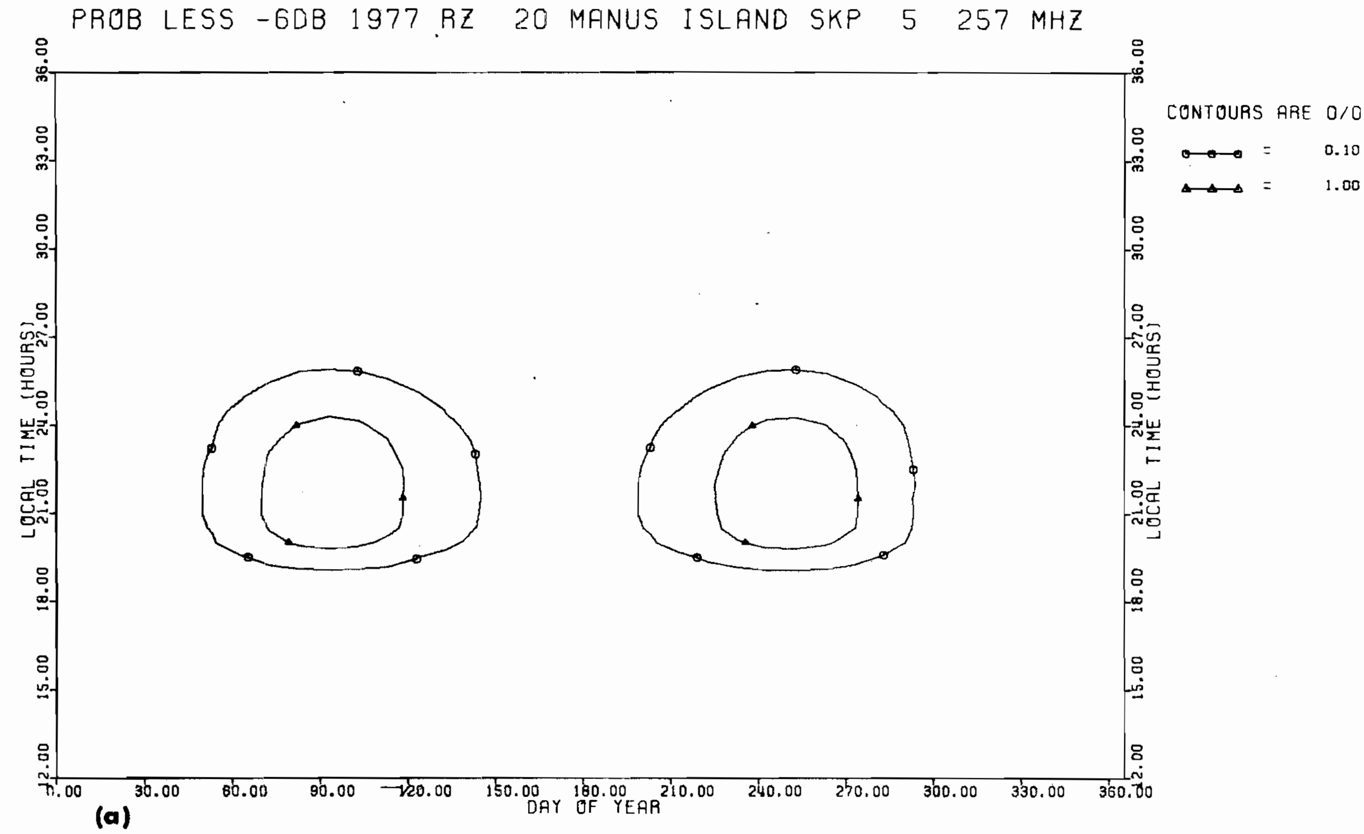


Figure 8. The effect of changing the critical level in the disruption probability calculations



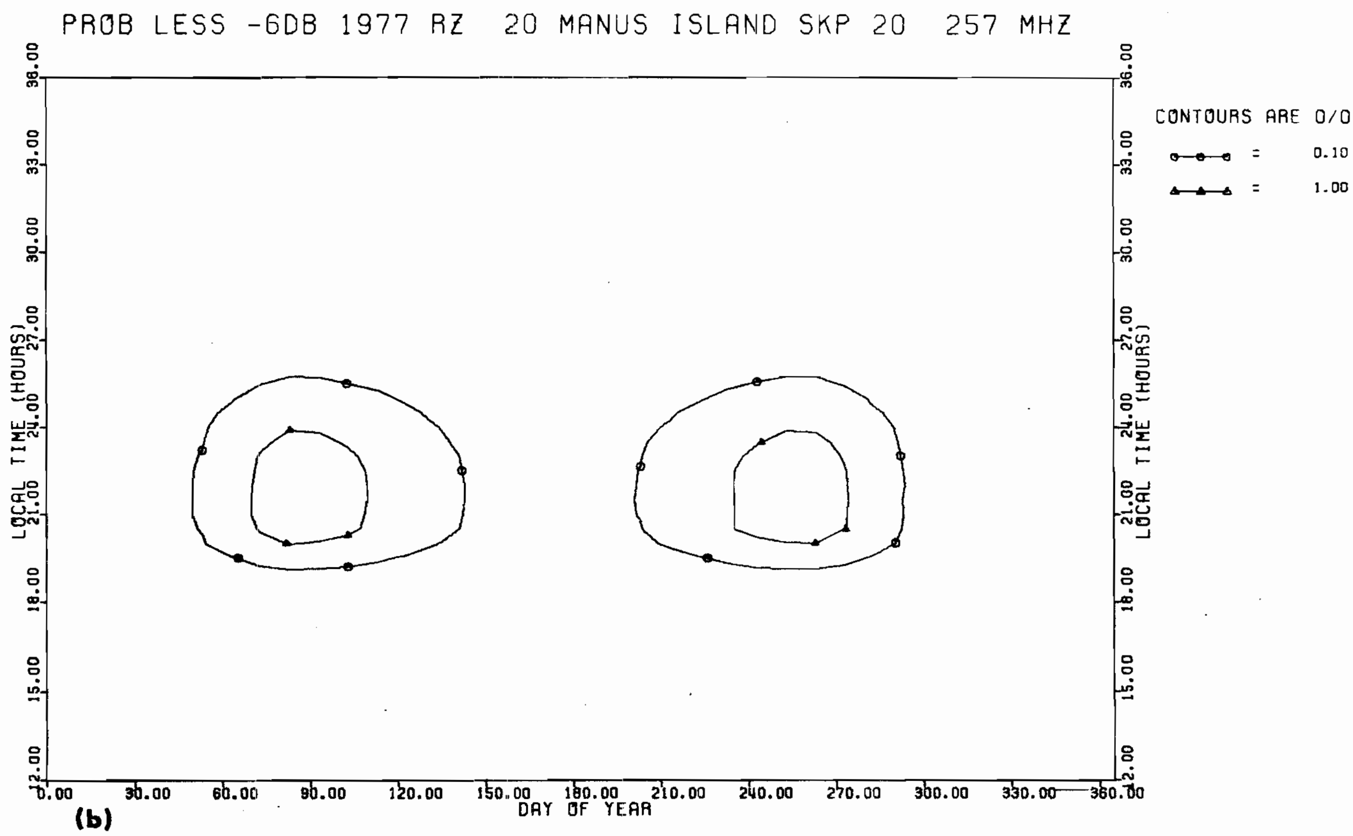
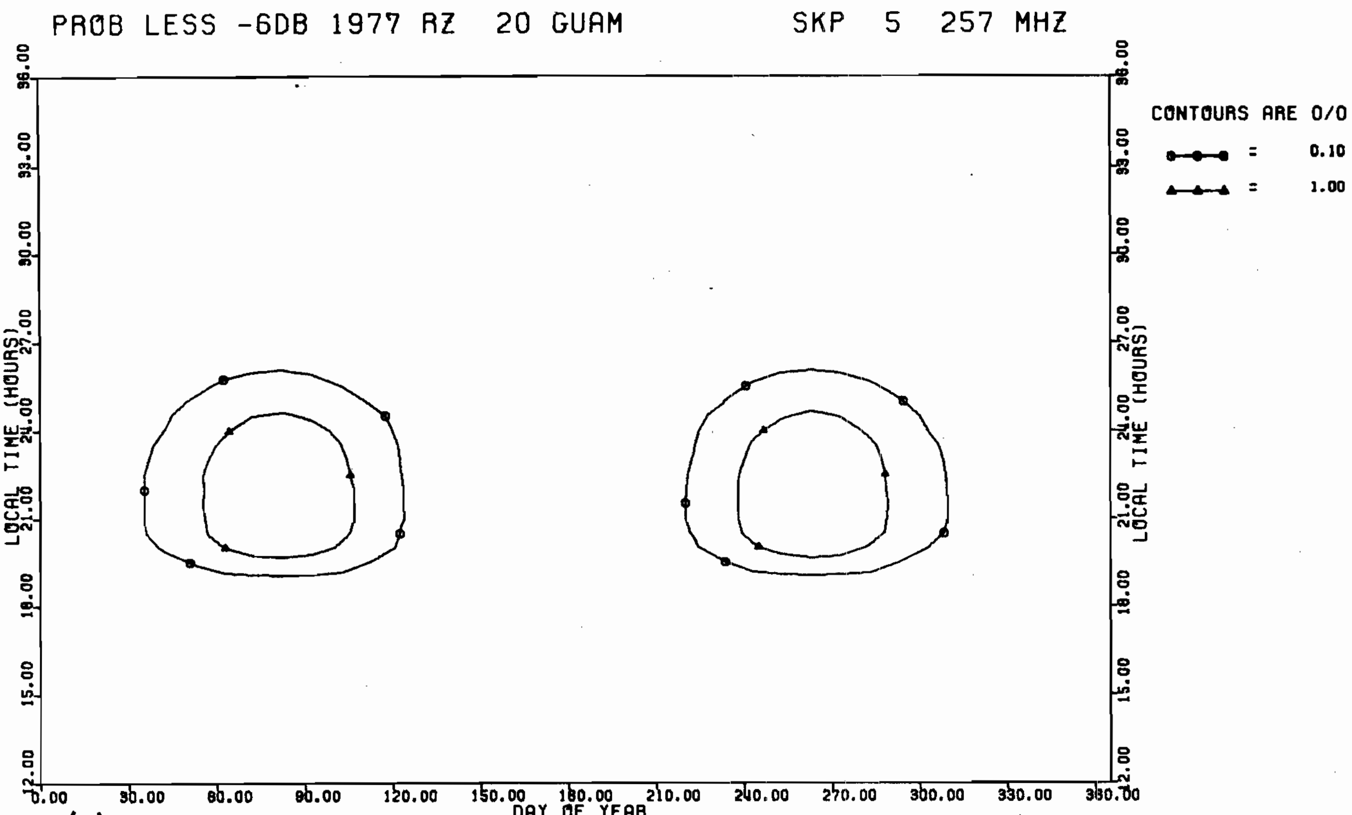


Figure 9. Diurnal and seasonal variations of propagation conditions on the Manus Island circuit



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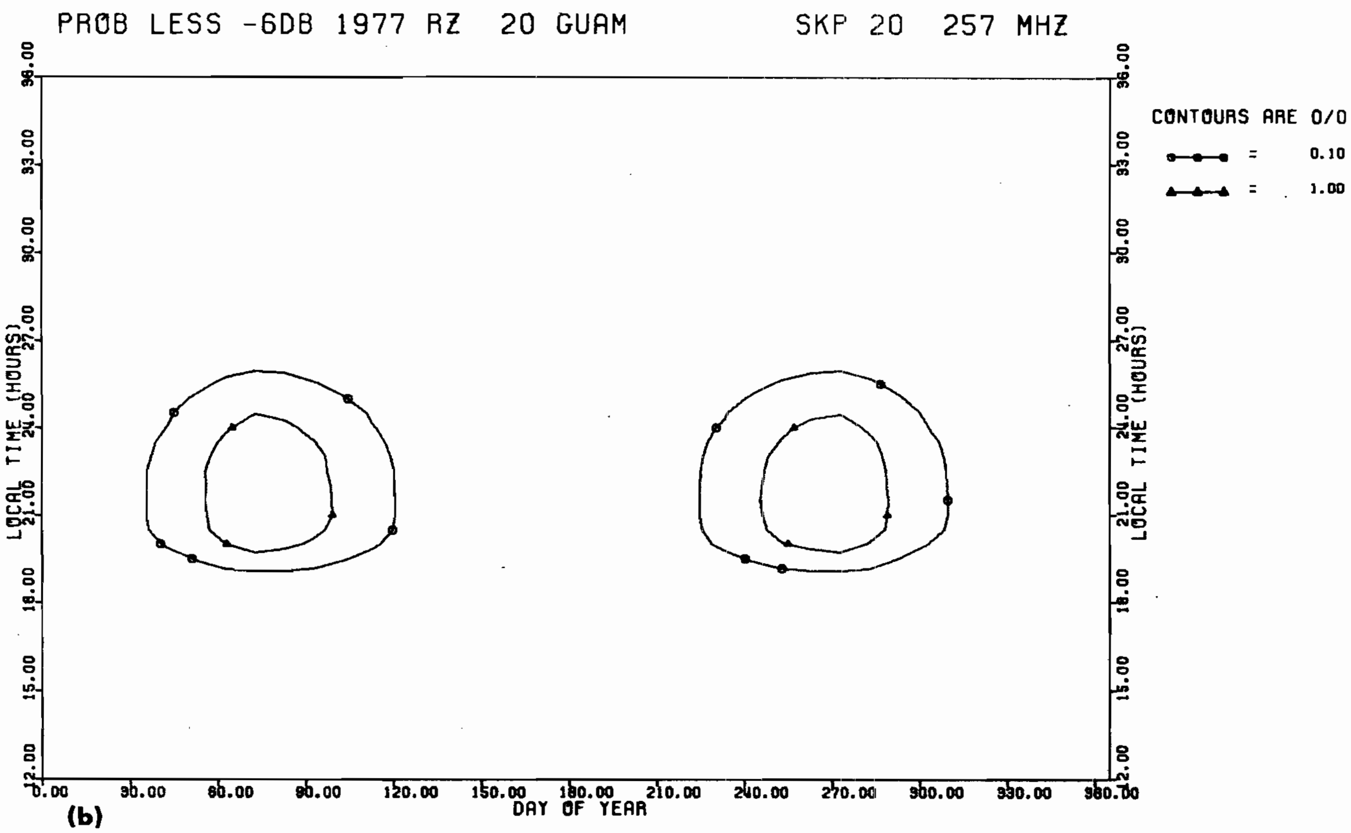
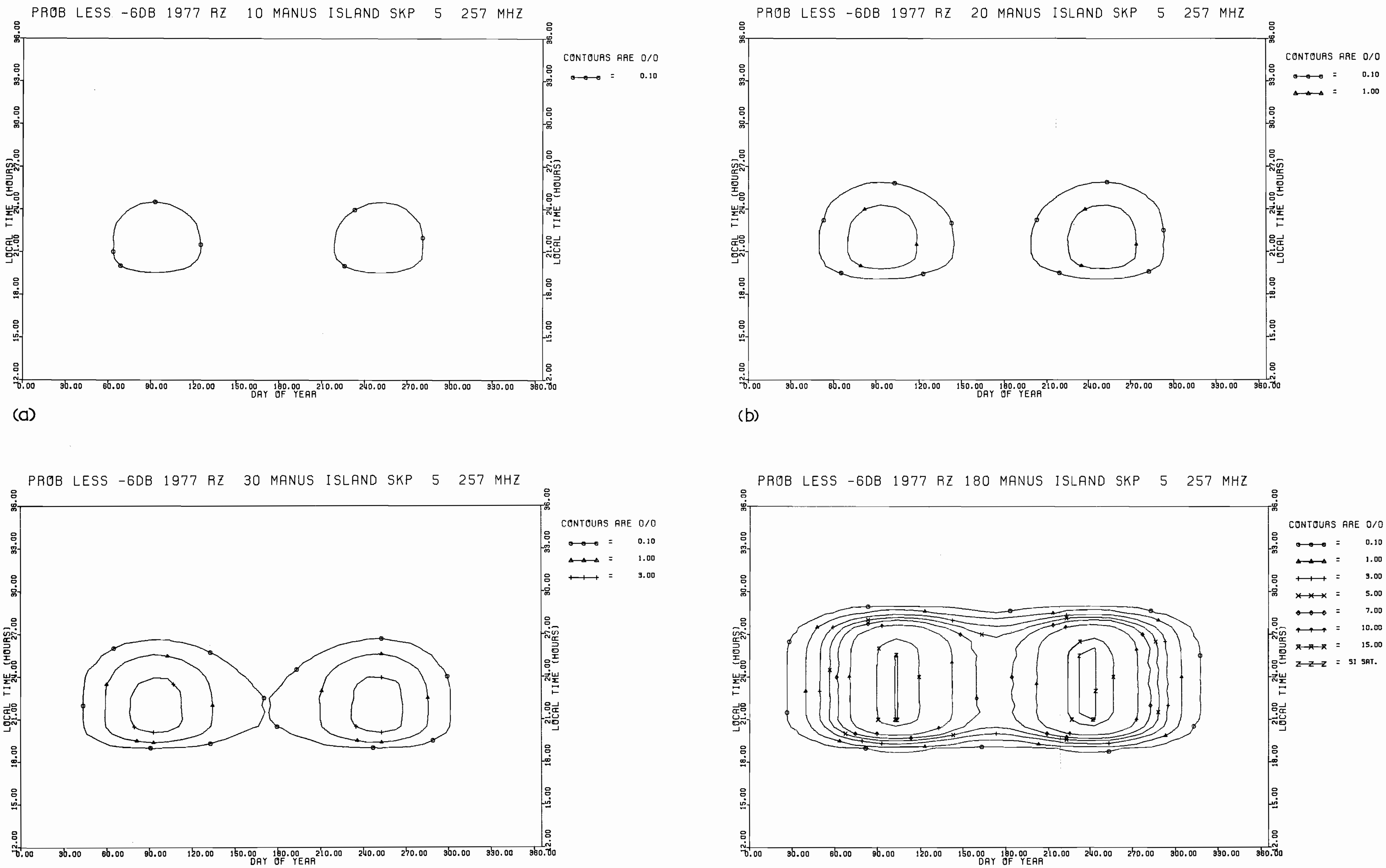


(b)

Figure 10. Diurnal and seasonal variations of propagation conditions on the Guam circuit



(c)

(d)

Figure 11. The effect of sunspot activity on the propagation conditions on the Manus Island circuit

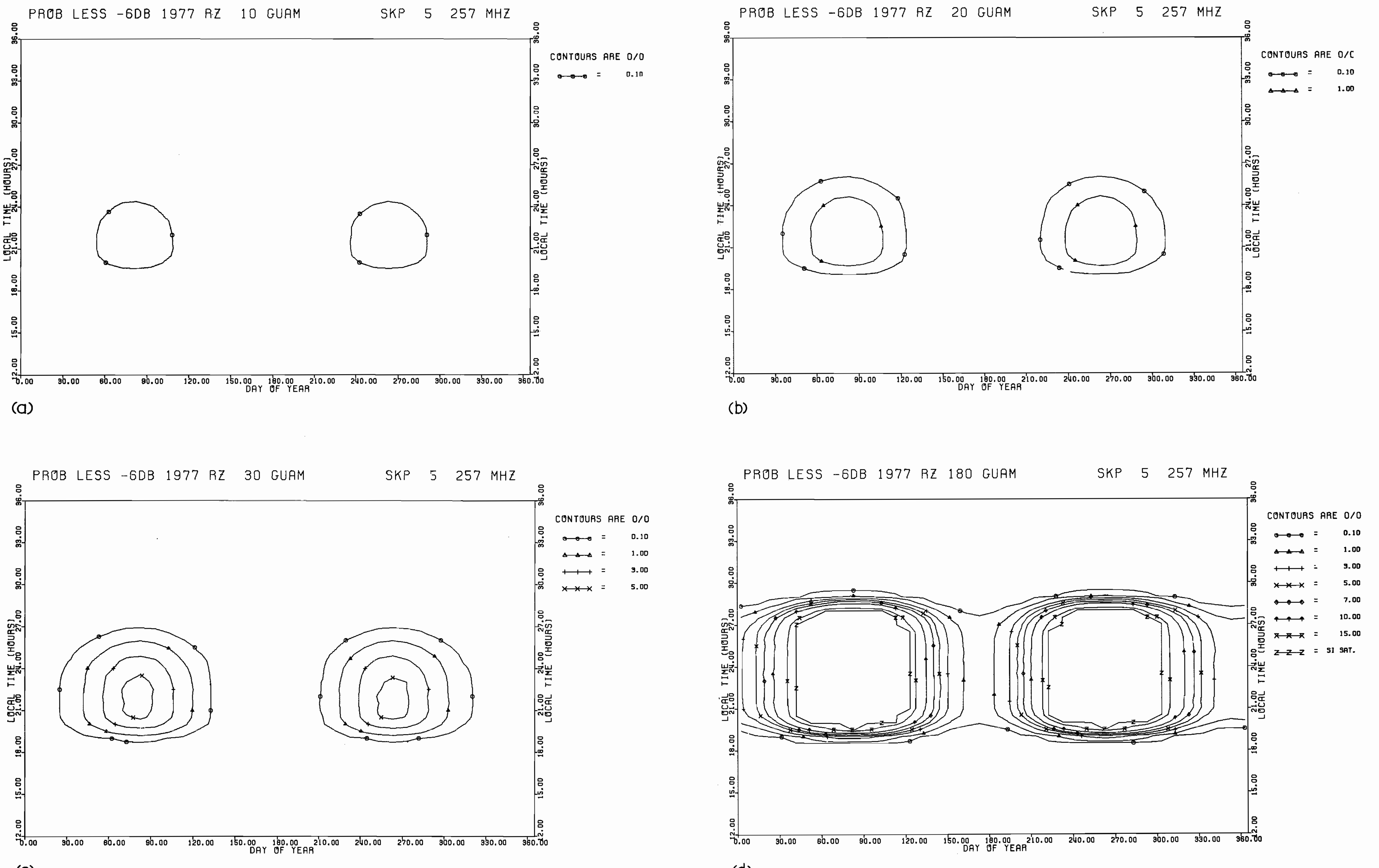


Figure 12. The effect of sunspot activity on the propagation conditions on the Guam circuit

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17 SUMMARY OR ABSTRACT:
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A scheme is developed for predicting propagation conditions on transionospheric circuits. The scheme combines a realistic model of F-region irregularity behaviour with thin screen scintillation theory in order to simulate both the mean scintillation index and the probability of the signal falling below a nominated level. Consideration is given to the application of the prediction scheme to transionospheric circuits terminated by a synchronous satellite at 176.5° E (e.g. MARASAT II) and by points on the Earth's surface within an area bounded in latitude by 30° N and 65° S and in longitude by 75° E and 270° E. The duirnal and seasonal variations of the probability of disruption of such circuits is investigated under varying conditions of magnetic and sunspot activity. It is concluded that circuits, which terminate in a large and strategically important equatorial region and a small high latitude region, are likely to be disrupted at night. In the equatorial region the possibility of disruption is (a) highest during the equinoxes, (b) reduced by magnetic activity and (c) particularly severe during years of high sunspot activity. The bearing these factors have on the operational use of transionospheric circuits is briefly discussed.

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